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A UNIVERSAL LASER SURVEYING INSTRUMENT. PART II.(U)  
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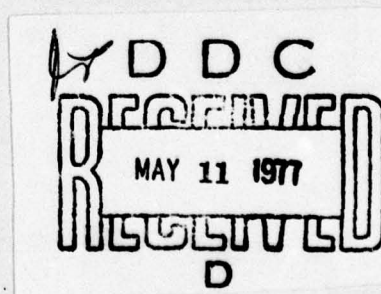
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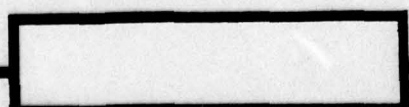
A UNIVERSAL LASER SURVEYING  
INSTRUMENT /Part II/

By

S. Pachuta, R. Kosciulewski, A. Gutkowski



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ULIG KP-4 - A UNIVERSAL LASER SURVEYING INSTRUMENT /Part II/  
Stanislaw Pachuta, Ryszard Kosciielewski, Andrzej  
Gutkowski

4. A verification of geometric conditions and a rectification of the instrument

THEODOLITE GEOMETRIC CONDITIONS

The KP-4 instrument should satisfy the following conditions:

- 1/ The alidade levels axes (II) should be square with the instrument vertical turn axis (VV);
- 2/ The main surface of the round, spherical level (pg) should be square with the instrument vertical turn axis (VV);
- 3/ The collimation surfaces of the aim axis and the sight telescope level axis should be parallel to each other;
- 4/ The aim axis of the sight telescope should be parallel to the collimation level axis;
- 5/ When changing a position of the sight telescope focusing device, the stability of the aim axis of the telescope should be preserved.
- 6/ When changing a focusing position of the transmitting telescope, the stability of the laser light beam symmetry axis should be preserved;
- 7/ The symmetry axis of the laser light beam should be coaxial with the optical axis of the transmitting telescope;
- 8/ The collimation surface of the laser light beam symmetry axis should go through the instrument vertical turn axis;



- 9/ The laser light beam symmetry axis should be square with the laser head level turn axis;
- 10/ The laser head level turn axis should be square with the instrument vertical turn axis;
- 11/ The collimation surfaces of the sight telescope aim axis and the laser beam symmetry axis should overlap;
- 12/ The laser light beam symmetry axis should be parallel to the sight telescope aim axis;
- 13/ The axis of the optical vertical should be coaxial with the instrument vertical turn axis;
- 14/ When having a level symmetry axis of the laser light beam, the reading taken from the vertical circle should be equal to zero;

When checking the instrument, one has to make sure the above geometric conditions have been satisfied. The checking procedure is performed according to the order described above. A failure to satisfy these conditions may result in instrumental errors. If any of the instrumental errors exceeds admissible values, an adjustment /rectification/ of the instrument is necessary.

A VERIFICATION AND A RECTIFICATION OF THE ALIDADE LEVELS PERPENDICULAR AXIS IN RELATION TO THE INSTRUMENT VERTICAL TURN AXIS

- a. One of the alidade levels is placed parallel to a line joining two accommodational screws.

By turning the two screws simultaneously in opposite directions,  
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By turning the two screws simultaneously in opposite directions, the middle of the blow-hole of the level is being reduced to the main point. By turning the third accomodational screw, the middle of the blow hole of the other alidade level is being brought to the main point.

b. The alidade is being turned by  $200^{\circ}$ , exact to  $\pm 1^{\circ}$ . If the position of the blow-holes does not change, the conditions of perpendicularity of the alidade level to the instrument vertical turn axis have been satisfied.

The admissible deviation of the blow-holes from the main points of the level is  $\pm 0.3$  of the level scale. If the blow-hole of any level deviates by more than  $\pm 0.3$  of the scale, a rectification of the level is needed.

When rectifying the first level, the first half of a deviation is corrected by means of two accomodational screws, and the second half of it is corrected through the use of the adjustment screws of the level.

Similarly, the first half of a deviation of the blow-hole of the second level is corrected by turning the third accomodational screw, and the second half of the deviation is corrected by turning the adjustment screws of the level.

The procedure described above must be repeated.

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A VERIFICATION AND A RECTIFICATION OF THE PERPENDICULARITY OF THE  
MAIN, ROUND, SPHERICAL (BOX) LEVEL TO THE INSTRUMENT VERTICAL TURN  
AXIS

Upon careful levelling of the alidade levels by means of accommodational screws, the blow-hole of the round, spherical level should occupy a centric position. Any possible deviation of the blow-hole should be corrected by means of the adjustment screws of this level.

A VERIFICATION AND A RECTIFICATION OF A RECIPROCAL PARALLELISM OF  
THE COLLIMATION SURFACES OF THE AIM AXIS AND THE SIGHT TELESCOPE  
LEVEL AXIS

- a. It is necessary to position the alidade in such a way that one of the accommodational screws lie exactly under the sight telescope.
- b. A levelling staff should be set up in the distance of 30-40 meters from the instrument, on the way of the aim axis of the sight telescope.
- c. It is necessary to achieve a coincidence of images of edges of the sight telescope level blow-hole through turning a vertical movement micrometer of the transmitting telescope /21/ , and afterwards read the levelling staff indications.



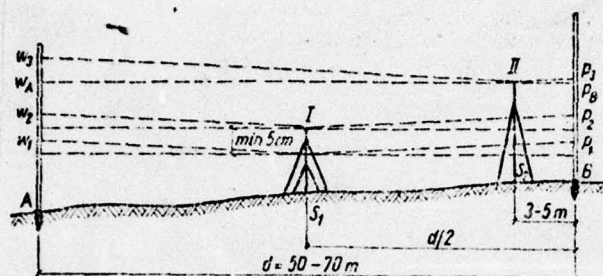


Fig. I2: A verification of the condition of parallelism of the aim axis to the levelling level axis:  
I - the first position of the instrument,  
II - the second position of the instrument

- d. The accommodational screw located on the left hand side of the telescope should be turned by  $180^\circ$ , and the screw located on the right hand side should be positioned in such a way that the previous reading be obtained in the telescope for the second time. If the collimation surfaces of the aim axis and the sight telescope level axis are parallel, the blow-hole of the sight telescope level should remain in the middle position.
- e. When the blow-hole of the level deviates from the middle, it is necessary to loosen a little the upper adjustment screw of the level and make coincide the images of edges of the blow-hole by means of the level /horizontal/ adjustment screws of the level.

#### A VERIFICATION AND A RECTIFICATION OF THE SIGHT TELESCOPE AIM AXIS AND THE LEVELLING LEVEL AXIS PARALLELISM

The verification is performed by means of the so-called double

levelling in the following order:

- a) Two pegs, distant 50-70 <sup>meters</sup> metres from each other (points A and B) should be set into the ground in a possibly darkened, wind-free area;
- b) The vertical levelling staffs should be set up on the pegs, and the instrument should be placed in the middle of the section (position #I), exact to 1 meter.

In the position #I /with two, at least 5 cm different horizons of the instrument/ a difference in height (h) between points A and B is twice determined by taking the readings from the levelling staffs  $w_1$  and  $p_1$  and also  $w_2$  and  $p_2$ . The difference:

$$h_1 = \frac{(w_1 - p_1) (w_2 - p_2)}{2}$$

does not carry the axis non-parallelism error. The values contained in parentheses cannot differ by more than  $\pm 2$  mm .

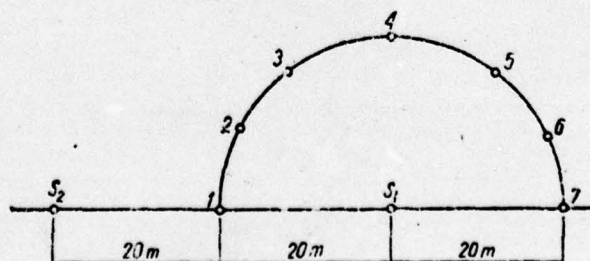


Fig.I3: A verification of the laser beam focussing device

Without changing the position of the staffs, it is now necessary to place the instrument near one of the staffs (for example B) in the distance of 3 - 5 meters (position #II), reading the indications of the staffs  $w_3$  and  $p_3$  and calculating the result of their subtraction

$$h_{II} = w_3 - p_3$$

The condition of the parallelism of the aim axis to the level axis may be deemed satisfied, if the  $h_{II} - h_1$  result does not exceed  $\pm 3$  mm.

If  $(h_{II} - h_1) > 3$  mm,

provided that

$$P_B = P_3,$$

then it is necessary to calculate the reading

$$W_A = h_1 + p_3$$

to which the aim axis of the telescope should be directed by turning the vertical movement micrometer of the transmitting telescope.

A level blow-hole deviation, which occurred due to this, is corrected through turning vertical adjustment screws of the level.

The work on position #II is repeated until an accordance between the differences in height  $h_1$  and  $h_{II}$  within the range of  $\pm (2+3)$  mm is achieved.



A VERIFICATION OF THE STABILITY OF THE AIM AXIS OF THE SIGHT TELESCOPE AFTER CHANGING A POSITION OF THE FOCUSING DEVICE OF THIS TELESCOPE

This condition does not need to be verified, as the existing assembly error which remained after a manufacturing process of the sight telescope has practically no effect on the aiming exactitude.

A VERIFICATION OF THE STABILITY OF THE LASER LIGHT BEAM SYMMETRY AXIS AFTER CHANGING A POSITION OF THE SIGHT TELESCOPE FOCUSING DEVICE.

a. In a flat area, within the radius of 20 meters away from the position of the instrument ( $S_1$ ), a number of pegs should be set into the ground, one about 10 meters away from the other, in the way that they form a semicircle. Moreover, one peg should be put at the production of the line AB at the distance of 20 meters from the point B.

b. In the position  $S_1$ , with a levelled level and an unchanged position of the sight telescope focusing device, readings should be taken from the levelling staff set at the points 1 - 7, respectively. The highest reading value corresponds to the top of the lowest peg. The other pegs

should be set the same way in order that the same readings on the staffs be obtained.

c. The instrument should be placed at the point  $S_2$ .

At that place readings should be taken from the levelling staff set on the same pegs from 1 to 7, respectively at a variable distance (from 20 to 60 meters), which makes one change constantly the position

of the telescope focusing device.

As soon as all readings are equal within the range of exactitude ( $2 \div 3$  m), the focusing device of the transmitting telescope will work properly, otherwise a correction in a repair shop is necessary.

#### A VERIFICATION OF THE COAXIALITY OF THE LASER LIGHT BEAM SYMMETRY AXIS TO THE TRANSMITTING TELESCOPE OPTICAL AXIS

a. Mark a geometry center of the transmitting telescope lens.

To do so, it is necessary to draw on a sheet of paper a net of concentric circles at the spaces of 2 mm. Next the sheet should be put on the lens in such a way that the circle, whose diameter approximates the diameter of the lens, coincide with the cover of the lens. The center of the circles will mark a geometrical center of the lens.

b. The laser light beam symmetry axis (the center of the beam) should be in line with the center of the circles. If it fails to do so, it is necessary to unscrew the nuts (3) and bring the center of the beam to the center of the circles by means of the adjustment screws of the laser head. If the laser beam is set properly, a spot of the laser light of a maximum intensity should be obtained on the sheet.

#### A VERIFICATION OF THE PASSING OF THE LASER BEAM SYMMETRY AXIS COLLIMATION SURFACE THROUGH THE INSTRUMENT VERTICAL TURN AXIS

The manufacturing factory guarantees the passing of the transmitting telescope optical axis collimation surface through the instrument vertical turn axis. By achieving the coaxiality between the laser beam symmetry axis and the transmitting telescope optical axis, a condition of the passing of the laser beam symmetry axis collimation surface through the instrument vertical turn axis will also be satisfied.

A VERIFICATION AND A RECTIFICATION OF THE PERPENDICULARITY OF THE LASER LIGHT BEAM SYMMETRY AXIS TO THE LASER HEAD LEVEL TURN AXIS AND THE PERPENDICULARITY OF THE LASER HEAD LEVEL TURN AXIS TO THE INSTRUMENT VERTICAL TURN AXIS

Since the turn of the telescope round the laser head level turn axis is impossible in the KP-4 instrument, the two conditions are being checked simultaneously in an indirect way by taking advantage of the influence of the errors on the level angle value.

Let be:

$\alpha$  - a real angle

$\alpha$  - an angle measured with the KP-4 instrument

$c$  - a collimation error

$i$  - an inclination error

$h_i$  - a vertical angle of aim

Considering a global influence of the collimation and inclination errors on the angle ( $\alpha$ ), the following formula is obtained:



-II-

$$\alpha = a + c(\sec h_1 - \sec h_2) + i(\operatorname{tg} h_1 - \operatorname{tg} h_2)$$

By marking:

$$\sec h_1 - \sec h_2 = A$$

$$\operatorname{tg} h_1 - \operatorname{tg} h_2 = B$$

$$\alpha' - \alpha = \Delta \alpha$$

we will obtain the formula:

$$A_c + B_i + \Delta \alpha = 0$$

Since the above equation has two unknown quantities  $c$  and  $i$ , to calculate them it is necessary to formulate a system of two equations.

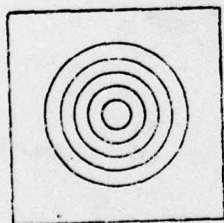


Fig.14: A net for marking a geometrical center of the lens.

This is possible in the case of the measurement of two angles whose values are known. When measuring the level angle, it is necessary to read the values of vertical angles of the aiming points.

THE ORDER OF ACTION WHEN MARKING THE QUANTITIES  $c$  AND  $i$ :

a. It is necessary to choose 4 points in an area, two of which

should be near the horizon plane, and the other two should be above the horizon, at an angle of  $h$ .

b. Measure standard angles  $\alpha_1$  and  $\alpha_2$ , exact to  $m = \pm 15''$ .

c. Measure the same angles with the KP-4 instrument.

d. Calculate the values of the collimation and the inclination (c and i). If  $c'' \ll 50''$  and  $i'' \ll 50''$ , the geometric conditions may be considered satisfied.

When the collimation error exceeds a permissible value, it should be corrected by changing the laser beam symmetry axis. To do so, it is necessary to apply the following procedure:

- set the laser beam symmetry axis in the proximity of the horizon plane (set the transmitting telescope at level);
- set a control target in the distance of (d) from the position of the instrument and aim thereat.

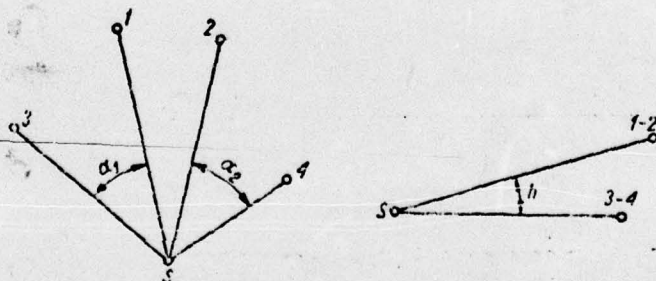


Fig. 15 : A schematic diagram of the arrangement of the points

- calculate the displacement value of the laser beam symmetric axis

$$Z = d \frac{c''}{p''}$$

where;

$Z$  = a displacement value in the target plane;

$d$  = a distance between the instrument position and  
the target;

$c$  = a marked collimation value /in seconds/

— shift the beam symmetry axis by the segment ( $Z$ ) by means of the  
rear adjustment screws;

In the case of finding the inclination error exceeding a permissible  
value, it is necessary to have the instrument corrected in a repair  
shop. After being through with the adjustment of the instrument, it is  
advisable to repeat the check on the last two geometric conditions.

A VERIFICATION AND A RECTIFICATION OF THE OVERLAP OF THE COLLIMATION  
SURFACES OF THE SIGHT TELESCOPE AIM AXIS AND THE LASER BEAM SYMMETRY  
AXIS AS WELL AS A CHECKUP ON THE PARALLELISM OF THE LASER BEAM SYM-  
-METRY AXIS WITH THE SIGHT TELESCOPE AIM AXIS

The above conditions are checked simultaneously. To this end, it is  
necessary to apply a control target with the marked square net which  
forms a local system of co-ordinates (Fig. 16).

The measurements are performed through aiming at the target placed at



the distances of 5, 10, 15, 20, 25, 30 meters respectively.

The measurement procedure is as follows:

- a) After marking the points in given distances, it is necessary to set up the target on a stand at the first point (in the distance of 5 <sup>meters</sup> metres);
- b) Aim at the center of the target with the sight telescope aim axis;
- c) Read on the target the laser beam symmetry axis deviation values ( $\Delta x$  and  $\Delta y$ ) - the center of the spot;
- d) Repeat the measurements taking the target readings at respective points;

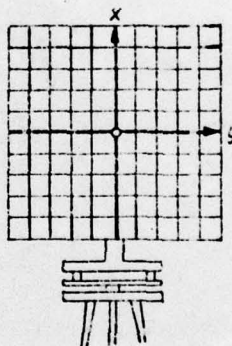


Fig. 16: A control target

- e) Determine the occurrence of errors by analysing  $\Delta x_1, \Delta y_1$  values obtained from the measurement of the laser beam symmetry axis deviation.

I. If the  $\Delta y$  values are equal at all distances quoted above, then the collimation surfaces of the sight telescope aim axis and the laser light beam symmetry axis are parallel; if, instead,  $\Delta y = 0$ , the collimation surfaces overlap each other.

The parallelism of the surfaces does not result in errors of the angles being measured, but may be inconvenient to an observer. In such cases, a rectification is unnecessary.

When  $\Delta y$  values are changing in a direct proportion to the distance, a rectification is needed (an intersection of the collimation surfaces occurs).

The rectification is achieved by shifting at a level plane the laser beam symmetry axis of the  $\delta y$  value calculated from the formula:

$$\delta y = \frac{30(\Delta y_{30} - \Delta y_5)}{25}$$

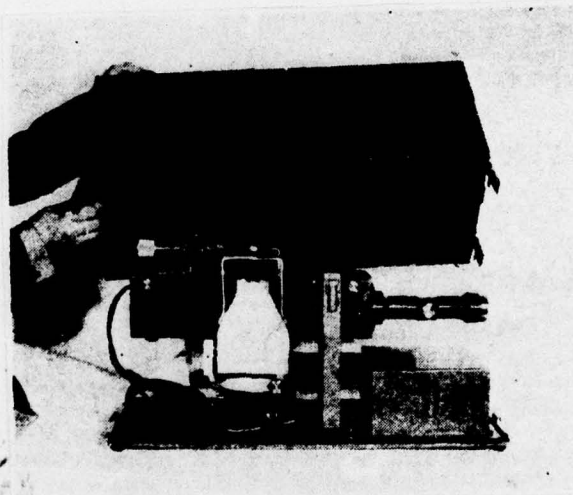


Fig. I7 : A picture of the theodolite in a transportation container

where  $\Delta y, \delta x$  - the aim axis displacement measured on the target set at the distance of 30 ~~m-tres~~ *meters*;

$\Delta y_{30}, \Delta x_{30}$  - the laser beam spot deviation from the aim axis at the distance of 30 ~~m-tres~~ *meters* from the target;

$\Delta y_5, \Delta x_5$  - the laser beam spot deviation from the aim axis at the distance of 5 meters from the target;

In order to make a shift of the sight telescope aim axis at a level plane, it is necessary to unscrew (release) the screws which fasten the sight telescope bedplate (10) and shift slightly the aim axis towards the laser light spot. Upon rectification it is necessary to check again the geometric conditions.

2. If the  $\Delta x$  values are equal at all distances, the condition of the parallelism of the sight telescope aim axis with the laser beam symmetry axis is satisfied.

When  $\Delta x$  values are changing in direct proportion to the distance, a rectification is necessary. To do that, one must calculate the necessary shift of the sight telescope aim axis at a vertical plane, according to the formula:

$$\delta x = \frac{30 \Delta x_{30} - \Delta x_5}{25}$$

Then, by turning the adjustment screw of the sight telescope (12) one must shift the sight telescope aim axis by the value of  $\delta x$  in the direction of the laser light spot.

#### A VERIFICATION OF THE COAXIALITY OF THE OPTICAL VERTICAL WITH THE INSTRUMENT VERTICAL TURN AXIS

In the instrument, the optical vertical built in the alidade has been applied. Upon exact levelling of the instrument it is necessary to mark



a point whose picture will be visible in the middle of the tick on the plate of the focal length of the optical vertical. The alidade should then be turned by  $200^g$ . The picture of the point should be in the middle of the plate tick. When the picture of the point deviates by more than 3 millimeters, a rectification is necessary by shifting the optical vertical plate towards the point by  $\frac{1}{2}$  of the deviation by means of the adjustment screws.

#### A VERIFICATION OF THE ZERO POINT OF THE VERTICAL CIRCLE

The order of action:

Level carefully the instrument by means of the alidade level. Then, set the transmitting telescope at level by means of the sight telescope level. Take the reading from the vertical circle, which is a zero point of this circle, when:

$$MO > 0^g$$

the vertical angle

$$\beta = 0 - MO$$

if:

$$MO < 400^g (0)$$

the vertical angle

$$\beta = 0 + MO - 400^g$$

#### 5. Transportation

The instrument is stored and transported at long distances in spe-

-cial containers (Fig.I7). There is enough room for the theodolite in such a container. The theodolite should be put into it cautiously, without the use of force, in a position indicated on the photo on the cover. The theodolite must not be transported on tough floors of any means of transportation.

The instrument can be transferred from one place to another, if fixed on a stand, only in a vertical position.

6. General principles of maintenance and utilization of the instrument

1. The laser radiation is harmful to the eyesight, therefore the light beam should not be directed into the eyes.
2. Upon completion of work it is necessary to clean the dust and the dirt off the theodolite, and the surfaces of the optical parts.
3. Fingers should be kept off the optical parts.
4. The outer surfaces of the optical parts are cleaned out by means of a cotton wool tampon reeled in a wooden stick soaked in a mixture of 50% of spirit and 50% of ether.
5. The mechanical parts of the instrument are cleaned out with a brush pencil and a dry, flannel wiper.
6. The instrument must be protected from occasional showers and a heavy insolation by means of a topographic umbrella.
7. The instrument must be stored in a dry, damp-proof place, away from corrosive substances.
8. The co-operating units should be oiled once in a year. In the case of discovering that the theodolite still turns with difficulty

round the vertical axis , despite a repeated strong turning, it is necessary to have the theodolite lubricated.

9. The theodolite may be taken to pieces only in a specialized surveying tools repair shop.

10. The legs clearances of the levelling head and directing mechanisms are eliminated by tightening the nuts by means of the adjustment needle.

11. A replacement of the unloading pipe or the feeder elements as well as an aligning of the laser may be carried out only in a specialized maintenance shop.

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